Far-Infrared Room-Temperature Focal Plane Modules for Polar Radiant Energy in the Far InfraRed Experiment

Giacomo Mariani, Matthew Kenyon, Byeong Eom, Brian Drouin, Mary White
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91125 USA

***Abstract*— This work presents focal plane modules for Polar Radiant Energy in the Far InfraRed Experiment, a passive remote-sensing instrument aimed to determine errors in the estimated outgoing longwave radiation in the Earth's polar regions to reduce uncertainties in surface emissivity, mass balance, and ice flux. The focal plane arrays are micromachined at JPL and integrated into sub-assembly modules to be mounted on the optical telescope of the instrument.**

I. INTRODUCTION

THERMOPILE detectors are widely used in applications that require accurate radiometry at ambient (uncooled) operation. Thermopile imagers do not require electrical bias, and generate voltages that are proportional to the input radiation signal. They have negligible 1/f noise and they are well suited for broadband and spectral radiometers for Earth and space science applications [1]. The mission goal is to reduce uncertainties in the surface and atmospheric components of the Arctic energy budget by, for the first time, providing systematic observations of the spectral variation of far-infrared fluxes across the Arctic annual cycle. The hybrid focal plane module assembly is built at JPL and it is composed of a thermopile detector array, four flight-qualified read-out integrated circuit (ROIC) with digital output. The ROICs are integrated with a printed wire assembly that terminates in a connector at the end to mate to the rest of the instrument. The calibration scheme of the instrument is designed to have the Polar Radiant Energy in the Far InfraRed Experiment (PREFIRE) focal plane module (FPM) periodically stare at a calibration target and space views to allow on-board temperature calibrations. The instrument will be capable of sampling a 5-54 µm spectral range at a spectral resolution of 0.84 µm.

II. MINIATURIZED CUBESATS

PREFIRE will fly miniaturized thermal infrared spectrometers on two CubeSat satellites, each about the size of a loaf of bread. The sensors are based on technology previously flown on the Mars Climate Sounder (MCS, *Figure 1*), an instrument on

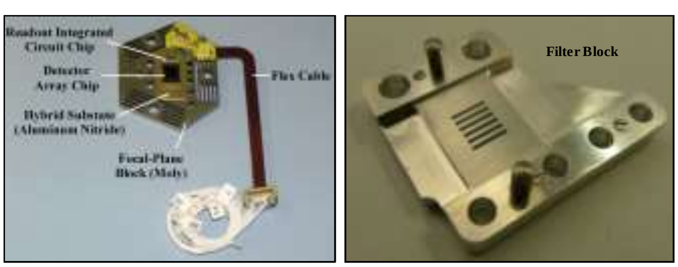

Figure 1: (Left) MCS focal plane module with flex cable connected. (Right) MCS filter block and alignment posts before integration with focal plane module.

NASA's Mars Reconnaissance Orbiter. The CubeSats will orbit Earth's poles to measure far-infrared emissions and how they change throughout the day and over seasons. For this type of application, miniaturization is key. Thermopile technology allows far-infrared imaging at room temperature, representing the core enabling technology for PREFIRE.

III. RESULTS

The PREFIRE detector consists of a 64-by-8 pixel thermopile array designed and arranged in a four-sided wiring bus routed to accommodate one ROIC wire bonded on each side of the detector (128 channels/side). The pixel array size is dictated by the point-spread function of the imaging/telescope system.

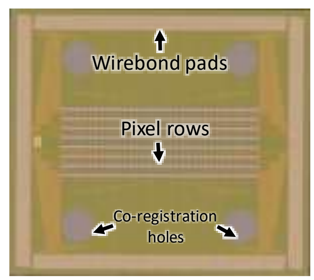

Figure 2: PREFIRE thermopile-based focal plane array.

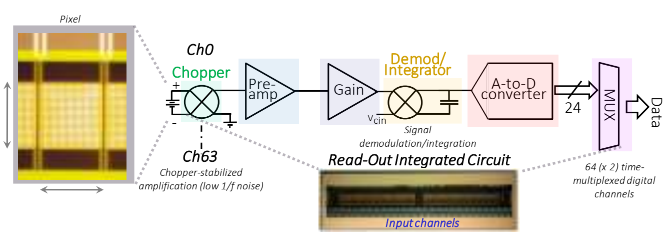

Figure 3: Read-out integrated chip designed by Black Forest Engineering.

Micro-machined PREFIRE thermopile detectors are based on bismuth-antimony-tellurium (Bi-Sb-Te) alloys. These alloys convert the incident power from the scene into a voltage signal via the thermoelectric Seebeck effect, and they are the heart of the sensor since they ultimately drive the signal-to-noise (SNR) of the imager [2]. In *Figure 2*, the PREFIRE focal plane detector array is shown. Wire bonding technology connects the array to four ROICs for a total of 512 channels. Subsequently, 'gold black', a highly efficient broadband coating layer, is deposited atop to achieve near unity absorption efficiency over wavelengths between 1-100µm. After fabrication, the detectors are screened to verify that responsivity and response time values, along with additional key parameters, are compliant. *Figure 3* shows a block diagram and a close-up picture of a ROIC before integration into the sub-module assembly. The

ROIC adopts chopper-stabilized technology to minimize the 1/f noise-frequency response. Via a sigma-delta analog-to-digital converter the ROIC delivers time-multiplexed 24-bit digital output signals on serial peripheral interface.

IV. SUMMARY

Surface- and bulk-micromachining of PREFIRE thermopile detector arrays and incorporation into a fully-integrated focal plane module assembly is presented as remote-sensing thermal imager in the payload of the CubeSat instrument [3].

V. ACKNOWLEDMENT

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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[3] Polar Radiant Energy in the Far-InfraRed Experiment. Source: https://science.jpl.nasa.gov/projects/PREFIRE/